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Adaptive coupling of different numerical methods*

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Abstract

In the simulation of problems in engineering different material behavior may occur in different parts of the analyzed domain. The behavior may range from continuum to dis-continuum behavior. Of the three main numerical methods used for the simulation some are better than others for modeling different physical phenomena. The Boundary Element Method (BEM) for example is best suited for elastic continuum problems, the Finite Element Method (FEM) has been found to work well for non-linear material problems and finally the Discrete Element Method (DEM) is ideally suited for modeling discontinuous behavior. However, in any given problem it may be difficult to determine a priori the type of behavior that is likely to occur in different parts of the problem domain. For example non-linear and discontinuous behavior may occur only in a small part, whereas the main part behaves elastically. An example of this occurs in underground excavation either in tunneling or mining. The idea proposed and reported here is to let the simulation program automatically determine the areas which need a different type of method and to automatically adapt the mesh during an analysis. The approach is to start with BEM analysis, assuming linear elastic behavior, and then determine the zone where the stress field is such that non-linear or discontinuous behavior is likely to occur (the criterion for discontinuous behavior would be for example the presence of tensile stresses that are higher than the tensile strength of the material). After this it is envisaged that the BEM mesh is changed to include a FEM or DEM mesh in parts that have been identified as being more suited to these models. This is then followed by a coupled analysis. Whereas the coupling of BEM/FEM is well established (Beer et al 2008), the coupling of BEM/DEM is more complex. The reason is that very different solution algorithms are used (implicit versus explicit) and the FEM/BEM work with stresses and strains, whereas the DEM works with particle contact forces. This requires some development of methods to transfer stresses from FEM/BEM to contact forces and the development of suitable coupling algorithms. Here we will present the adaptive strategy, the transfer of stresses to the DEM and the iterative coupling strategy that has been adopted. Test examples are presented to demonstrate the applicability of the developed methodology.

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